The Effect of Simple Versus Complex Carbohydrates

on

Mood and Plasma Glucose and Tryptophan Levels

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Abstract

Subjects either fasted, or consumed lunch time test meals consisting primarily of simple carbohydrate, complex carbohydrate, or protein. Mood measures consisting of the Profile of Mood States(POMS), the Stanford Sleepiness Scale (SSS), and the Activation-Deactivation Adjective Checklist (AD ACL), and plasma glucose and tryptophan levels were assessed prior to meals, at 30, 60, 120 and 180 minutes following meal consumption. All conditions produced an initial decline in POMS tension ($p<0.0001$), depression ($p<0.0002$), anger ($p<0.0001$), vigor ($p<0.01$), and confusion ($p<0.01$) scores, and in the AD ACL tension score ($p<0.01$), possibly due to a general postprandial effect or an acclimation to experimental conditions. A significant time by meal condition interaction effect ($p<0.05$) was found for the AD ACL tension scores. The simple carbohydrate meal produced the greatest initial and net decrement in tension, possibly due to the high elevation in plasma glucose levels also produced by this meal. The decrease in tension caused by the simple carbohydrate meal and protein meal, and the smaller decrement in tension induced by the complex carbohydrate meal, occurred independently of fluctuations in the plasma tryptophan/LNAA ratios. These results contradict with the current understanding of carbohydrates influence on tryptophan levels and behavior and necessitate further research on the effects of simple versus complex carbohydrates on mood, and on the mechanisms through which these effects may be occurring.

The Effect of Simple Versus Complex Carbohydrate and Protein Meals on Mood

In light of recent growth in health consciousness in society and current research findings, the effect of carbohydrates on behavior has become of increasing interest to laypeople and scientists. Popular beliefs about carbohydrates' influence on behavior range from the proverbial post lunchtime slump in energy and performance, to the quick energy boost of a sugar snack. The effects of carbohydrates on mood may be of particular interest to obese individuals (Hopkinson & Bland, 1982; Wurtman et al., 1985), and to individuals experiencing Seasonal Affective Disorder (Rosenthal et al., 1984), premenstrual syndrome (Reid, 1985), postpartum depression (Dalton, 1980), or nicotine withdrawal (Grunberg, 1982). People in these subgroups have been found to selectively crave carbohydrates, indicating the influence carbohydrates may be exerting on mood and behavior Spring, Chiodo, & Bowen, 1987).

In a cross sectional investigation, Spring, Maller, Wurtman, Digman, and Cozolino (1983) found a high carbohydrate load produced a general decrement in tension and concentration, and induced sleepiness in females and calmness in males. High carbohydrate meals have been found to decrease alertness and increase sleepiness and fatigue when tested individually (Lieberman, Wurtman, & Chew, 1986), and in comparison to a high protein meal and balanced meal (Lieberman, Spring, & Garfield, 1986), and to no meal (Spring, Chiodo, Harden, Bourgeois, Lutherer, Harner, Crowell, & Swope, 1986).

In addition to their fatiguing effects, carbohydrates have been related to clinical and transitory depression. Sucrose has been indicated to increase fatigue, moodiness, nervousness, and depression in clinically depressed and nondepressed individuals identified as dietary responders in single subject designs (Christensen & Burrows, 1990; Kreitsch, Christensen, & White, 1988). Lieberman, Wurtman, and Chew (1986) also documented that a high carbohydrate meal increased depression in non-carbohydrate cravers.

Fluctuations in blood glucose levels and tryptophan ratios are currently being investigated as two possible mechanisms through which carbohydrates produce their effect on mood. Simple carbohydrates like sucrose cause a more dramatic rise and fall in plasma glucose than do complex carbohydrates, which are digested more slowly then sucrose. Such fluctuations may account for the dramatic increase in fatigue experienced after consuming sugar (Reaven, 1979).

Carbohydrates and protein meals have been demonstrated to alter the synthesis and release of brain serotonin through affecting the uptake of its amino acid precursor, tryptophan, from the bloodstream (Fernstrom & Wurtman, 1972). Tryptophan competes with other large neutral amino acids (LNAAs) in the blood for transport across the blood-brain barrier. Although the body receives its nutritional supply of tryptophan and the other amino acids from protein rich foods, a high-protein meal does not elevate brain tryptophan nor serotonin. This occurs because protein contains little tryptophan in comparison to the other LNAAs, and thus increases the competition between tryptophan and the other LNAAs for uptake into the brain. Therefore, the net result of a high protein meal is to decrease plasma tryptophan/LNAA ratios, and reduce the brain's serotonin synthesis and release (Spring, et al., 1986).

Conversely, a carbohydrate-rich, protein-poor meal increases the plasma tryptophan/LNAA ratio and consequently increases brain serotonin synthesis and release (Spring et al., 1986; Spring, Harris, Lieberman, Swope, & Garfield, 1986). Carbohydrates trigger insulin secretion which causes a fall in the plasma levels of the competing LNAAs. Tryptophan levels do not decline because tryptophan binds to albumin that has been liberated from free fatty acids by the insulin. The tryptophan/LNAA ratios are documented to be significantly elevated in human subjects after a high carbohydrate meal (Lieberman, Spring, & Garfield, 1986).

It is demonstrated that serotonin plays a role in inducing sleep, which may account for the fatiguing effects of carbohydrates. Lieberman, Spring, and Garfield (1986) found that tryptophan administered alone had a sedative effect on mood. In addition, carbohydrate and protein meals produced an increase and decrease of tryptophan levels, respectively, with sucrose and starch meals producing equal fluctuations in tryptophan levels. These results mirror the fatiguing effects of carbohydrates on mood, thus supporting the assumption that the carbohydrate induced elevation of the tryptophan ratio is a plausible mechanism for action (Lieberman, Spring, & Garfield, 1986; Spring et al, 1986; Spring, Lieberman, Swope, & Garfield, 1986).

When reviewing the literature on diet and behavior, methodological limitations need to be considered. Spring et al (1983) compared post prandial measurements between conditions, without measuring the baseline mood levels. None of the previously mentioned studies accounted for the distinction between simple and complex carbohydrates within a single experimental design. Evidence exists to support further investigation of simple versus complex carbohydrates as isolated dietary constituents. A high simple carbohydrate load appears to produce a more pronounced decrease in alertness (Spring, et al., 1983) than does a high complex carbohydrate load (Lieberman, Spring, & Garfield, 1986), and Christensen and Burrows (1990) have indicated refined sucrose specifically exacerbates depression in sensitive individuals. If blood glucose levels do indeed affect mood, then the greater elevation in plasma glucose levels caused by simple carbohydrates over complex carbohydrates (Crapo, Reaven, & Olefsky, 1977), may affect the experimental results. Although simple and complex carbohydrates affect tryptophan ratios equally, it is possible that they could produce differential effects on behavior. In addition. when simple versus complex carbohydrate loads are embedded in a balanced meal, they fail to yield any significant change in mood (Smith, Leekum,Ralph, & McNeill, 1988).

The purpose of the present study is to investigate the possible differential effects of simple versus complex carbohydrates on mood individually, and in comparison to a high-protein meal and fasting condition. The simple carbohydrates, complex carbohydrates, and protein were isolated as the primary nutrients in each test meal, and mood measures were taken before the meal and compared across time intervals afterward. Plasma glucose levels and tryptophan/LNAA ratios were measured to replicate previous findings and possibly offer an explanation for the observed changes in mood. Based on previous findings (Christensen & Burrows, 1990; Kreitsch, Christensen, & White, 1988; Spring, Lieberman, & Garfield, 1986; Bantle, et al., 1983; Spring, et al., 1983; Reaven, 1979), simple carbohydrates were expected to produce the greatest decrement in mood.

Method

Subjects

Subjects were twenty-seven nondepressed, healthy female Introductory Psychology students from Texas A & M University (M age= 18.6 years). All subjects scored $\leq$ 14 on the Beck Depression Inventory (BDI) (M= 6.5), and were average body weight (M = 126 pounds) according to the Metropolitan Life Insurance Company's height-weight tables (Stare, & McWilliams, 1981). Four subjects failed to provide body weight. Subjects were excluded from the study if they had diabetes, hypoglycemia, anemia, or any other medical condition which would confound the dietary intervention or interfere with the blood drawing procedures.

Females were chosen because they are more highly represented in subgroups identified as having selective carbohydrate cravings, such as individuals suffering from obesity (Hopkinson & Bland, 1982; Wurtman et al., 1985), Seasonal Affective Disorder (Rosenthal et al., 1984), premenstrual syndrome (Reid, 1985) and postpartum depression (Dalton, 1980). In addition, a homogeneously female sample would control for any gender differences in the reaction to carbohydrates and protein as evidenced by Spring and associates (1983).

Test Meals

Simple carbohydrate, complex carbohydrate, and protein test meals were prepared. Sucrose was the primary component of the simple carbohydrate meal which consisted of 1 cup Sugar Corn Pops, 1 cup low fat milk, one half cup vanilla ice milk, and 4 tablespoons marshmallow cream. The complex carbohydrate meal consisted of 2 1/2 cups cooked white long grain rice with 1 tablespoon margarine and seasoning. The protein meal consisted of a 6 ounce broiled chicken breast with 1 tablespoon italian salad dressing, 2 ounces mozzarella cheese, and 3 saltine crackers. Nutrient composition of test meals appears in Table 1.

Insert Table 1 about here

Mood Measures

Three self report questionnaires were used to measure mood: The Stanford Sleepiness Scale (SSS), Profile of Mood States (POMS), and The Activation-Deactivation Adjective Checklist (AD ACL). The Stanford Sleepiness Scale is a checklist of 7 graded sets of adjectives describing overall levels of arousal, and has been used in several other studies investigating diet and behavior (Lieberman, Spring, & Garfield, 1986; Spring, et al., 1986; Spring, Maller, Wurtman, Digman, & Cozolino, 1983; Hartman,Spinweber, & Fernstrom, 1977). The POMS consists of 65 adjectives, each of which is rated on a 5-point scale providing an index of tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia, and confusion-bewilderment (McNair, Lorr, & Droppleman, 1971). The AD ACL consists of 20 adjectives describing energetic and tense arousal, each rated on a 4-point scale. These are grouped into four subscales: Energy (General Activation), Tiredness (Deactivation-Sleep), Tension (High Activation), and Calmness (General Deactivation) (Thayer, 1989).

Procedure

Subjects fasted overnight and consumed a standard breakfast between 8:00 a.m. and 9:00 a.m., consisting of one of the following: 1 cup unsweetened cereal with 1 cup milk, and a piece of fruit or 6 ounces orange juice, or 1 egg with 2 pieces toast, 2 tablespoons margarine, and 1 piece of fruit or 6 ounce glass of orange juice. No additional snacks nor caffeinated beverages were allowed with breakfast or in between breakfast and the test time.

Upon arriving at the experiment site, subjects were randomly assigned to consume a lunchtime meal consisting primarily of simple carbohydrates, complex carbohydrates, or protein, or a delayed balanced meal to be served after the testing period was over. The test meals were served as lunch at 1:00 p.m. and subjects were allowed 15 minutes to consume the meal. All but one subject in the protein condition finished the entire meal. The SSS, POMS, and AD ACL were administered and a intravenous blood sample was drawn immediately prior to, and at 30 minutes, 1, 2, and 3 hours following completion of the test meal. Subjects were monitored in the same room throughout the study and watched informational videos between assessment periods.

Blood Sample Analysis

Blood samples were centrifuged and the plasma was stored at 0 C. Plasma glucose levels were analyzed using hexakinase spectrophotometric procedure (Sigma Chemical Co., 1991).

For amino acid analysis, plasma was prepared with *o*-Phthalaldehyde-mercaptoethanol reagent according to procedures outlined in Joseph and Davies (1983). The prepared samples were then analyzed through fluorometric detection on a reversed-phase high-performance liquid chromatographic (HPLC) column, and the tryptophan to large neutral amino acid or tryptophan/LNAA ratios were computed. The large neutral amino acids used for comparison were methianine, valine, phenylalanine, isoleucine, and leucine.

Results

Plasma Glucose Levels

Plasma glucose levels were analyzed by a mixed models analysis of variance (ANOVA) with the between effect being meal condition, and the within effect being assessment time. This analysis revealed a significant main effect of time $F(4, 92)= 4.72$, $p<0.002$, and a significant meal condition effect, $F(3,23)=5.3$, $p<0.006$.

Figure 1 depicts the blood glucose values across time for each meal condition. From the graph, it can be seen that the simple carbohydrate meal produced the greatest rise in plasma glucose levels and that the delayed meal produced virtually no alteration across time. Figure 1 also reveals that the largest increase in plasma glucose was measured at 30 minutes after meal consumption for the test meal conditions.

Insert Figure 1 about here

Plasma Tryptophan Levels

Tryptophan to Large Neutral Amino Acids (tryptophan/LNAA) ratios were calculated for two subjects in the complex carbohydrate condition, and for one subject in each of the other conditions.

The plasma tryptophan levels presented in Figure 2 reveal that the protein meal caused a constant decrease in the tryptophan/LNAA ratio from baseline to 3 hours after consuming the test meal. Conversely, subjects who consumed the complex carbohydrate meal showed a gradual increase in the tryptophan/LNAA ratio. The tryptophan/LNAA ratio of subjects who consumed the simple carbohydrate load and of subjects in the delayed condition did not change substantially across time.

Insert Figure 2 about here

Mood Measures

The SSS scores and each of the POMS and AD ACL scales were analyzed by a mixed models ANOVA factorial design with the between effect being meal condition and the within effect being assessment time. From Table 2, it can be seen that a significant time effect exists for scores on the POMS tension ($F(5, 110)=13.39$, $p<0.0001$), depression ($F(5, 110)=5.33$, $p<0.0002$), anger ($F(5, 110)=9.12$, $p<0.0001$), vigor ($F(5, 110)=3.73$, $p<0.01$), and confusion ($F(5, 110)= 3.76$, $p<0.01$) scales, and for the AD ACL tension scale ($F(5, 110)=3.59$, $p<0.01$).

Insert Table 2 about here

The most dramatic change in mood factors occurred at 30 minutes after the test meals were consumed. Mean scores on POMS tension, depression, anger, and confusion scales, and AD ACL tension scale decreased most dramatically at 30 minutes for subjects in all conditions, and then remained fairly constant for all subsequent time intervals.

Vigor decreased almost consistently across time, with subjects in the simple and complex carbohydrate conditions showing a slight increase 90 minutes after the test meal.

Insert Table 3 about here

Tension, as measured by the AD ACL also showed a significant time by meal condition interaction effect $F(5, 15)=1.85$, $p<0.04$). The mean scores depicted in Table 4 show the differences between conditions. The simple carbohydrate meal produced the most pronounced decrease in tension 30 minutes postprandium, which then rose slightly 1 hour postprandium and then continued to decline to well below baseline at 3 hours. The complex carbohydrate meal, however, caused an increase in tension at 30 minutes, followed by a decline below baseline at 1, 2, and 3 hours after the meal. The protein meal produced a continual decline in postprandium tension, until 3 hours after the meal when it rose slightly. Fasting caused an initial decrease in tension followed by a gradual increase from 30 minutes postprandium to 2 hours postprandium, then dropped markedly from 2 to 3 hours postprandium.

Insert Table 4 about here

Discussion

The differences in plasma glucose levels across time and between meal conditions agrees with current research findings (Spring et al., 1986; Bantle, et al., 1983). The simple carbohydrate meal provides the most readily available glucose load resulting in the greatest elevation in plasma glucose levels compared to complex carbohydrates and protein.

Although there is only a small representation of samples analyzed for tryptophan, the respective increase and decrease in tryptophan/LNAA ratios produced by the carbohydrate and protein meals also is consistent with the literature (Spring, Chiodo, & Bowen, 1987; Spring, et al., 1986; Spring, Lieberman, & Garfield, 1986; Spring, Lieberman, Swope, & Garfield, 1986; Glaeser, Maher, & Wurtman, 1983; Fernstrom, & Wurtman, 1972). The high protein meal produced a decline in the tryptophan/LNAA ratio by increasing the amount of the other LNAAs present in the blood relative to tryptophan. The high-complex carbohydrate, low-protein meal caused the tryptophan/LNAA ratio to increase over time. The simple carbohydrate meal, however, did not produce the expected increase in the tryptophan ratio (Spring, Lieberman, & Garfield, 1986). In fact, the values more closely resembled the those of fasting subjects, which showed little absolute change. This is probably due to the fact that the small amount of milk protein in the simple carbohydrate meal (8%) counteracted the effect of the sucrose, providing evidence of the delicate threshold of protein and carbohydrate's effect on plasma amino acids. The subject in the simple carbohydrate condition did have a lower baseline tryptophan/LNAA ratio than subjects in the other conditions, however, the relative change was still minimal. An increase in test samples is needed to minimize the baseline differences and support these findings.

The initial decrement in mood across conditions as indicated by the POMS tension, depression, anger, vigor, and confusion scales, and the AD ACL tension scale, could be an indication of a general postprandial sedative effect, as evidenced by Smith, Leekum, Ralph, and McNeill (1988). Smith and his associates found that after lunch time, subjects felt more lethargic, feeble, clumsy, muzzy, dreamy, bored, and mentally slow regardless of whether they consumed a simple carbohydrate, complex carbohydrate, or protein balanced meal. The fact that the subjects in the delayed condition experienced less of a decline in these aspects of mood, and even showed an increase in confusion as indicated by the POMS, and in tension as measured by both the POMS and AD ACL scales over time, supports the possibility of a generalized postprandial effect. Fasting subjects have been found to have increased levels of activation, and lower levels of fatigue than their cohorts who consumed a test meal (Smith, Leekam, Ralph, & McNeill, 1988), possibly due to hunger and increased adrenalin levels. The elevated measurement at 3 hours of subjects in the protein condition may also be due to hunger, or possibly the anticipation of the end of the experiment.

Due to the fact that fasting subjects also displayed an overall decrement in mood on the POMS scales, it can be concluded that a combination of meal consumption and acclimation to the testing environment is responsible for the observed changes in mood. Subjects appeared to be apprehensive about having blood drawn, and about the experimental setting and procedure in general, as evidenced by elevated baseline scores on the POMS tension, depression, anger, vigor, and confusion scales. Their nervousness may have simply declined as they became accustomed to the environment and procedure.

The decrement in tension demonstrated in the simple carbohydrate and protein conditions, seemed to occur regardless of the observed changes in the tryptophan levels. The simple carbohydrate meal produced no change in tryptophan/LNAA ratios, and the protein meal actually produced a decrease in the plasma tryptophan/LNAA ratio. However, both conditions still showed a decline in tension over time. These findings conflict with current research which attributes carbohydrates' fatiguing and calming effects, including the reduction of tension, to the increase in the tryptophan ratio induced by a high carbohydrate load, when observed singly and in comparison to high protein meals (Spring, Chiodo, & Bowen, 1987; Spring, et al., 1986; Spring, Lieberman, & Garfield, 1986; Spring, Lieberman, Swope, & Garfield, 1986; Glaeser, Maher, & Wurtman, 1983; Fernstrom, & Wurtman, 1972). The net decrease in tension produced by the simple carbohydrate and protein meals may further support a postprandial effect, acclimation effect, or some other mechanism occurring independently of fluctuations in plasma tryptophan levels.

The pronounced decrement in tension levels on the AD ACL in the simple carbohydrate condition may have been due to the elevated plasma glucose levels also caused by this test meal. The maximum decrease in tension in the simple carbohydrate subjects coincided with the greatest increase in plasma glucose level at 30 minutes.

According to Reaven (1979), fatigue usually occurs after sugar intake because the blood glucose levels rise dramatically, then fall in response to insulin. However, this explanation may not fully account for the differential effects of simple versus complex carbohydrates on tension. The complex carbohydrate still raised plasma glucose levels, although to a lesser degree than simple carbohydrate meal, yet at 30 minutes elicited an opposite effect on tension as the simple carbohydrate meal.

Although complex carbohydrates increased tryptophan levels and decreased net tension from baseline to 3 hours, a closer investigation of tension patterns in the complex carbohydrate condition reveals some discrepancies with the theory that carbohydrates reduce tension by elevating tryptophan/LNAA ratios (Spring, Chiodo, & Bowen, 1987; Spring, et al., 1986; Spring, Lieberman, & Garfield, 1986; Spring, Lieberman, Swope, & Garfield, 1986; Glaeser, Maher, & Wurtman, 1983; Fernstrom, & Wurtman, 1972). The complex carbohydrate meal increased tension slightly at 30 minutes and produced a net decline in tension that was much smaller than that observed in the simple carbohydrate condition or reported in current literature (Spring, Chiodo, & Bowen, 1987; Spring, et al., 1986; Spring, Lieberman, & Garfield, 1986; Spring, Lieberman, Swope, & Garfield, 1986; Lieberman, Wurtman, & Chew, 1986; Spring, et al., 1983). Since many of these studies of carbohydrates' effect on mood combined both simple and complex carbohydrates in their test meals, (Spring, et al., 1986; Lieberman, Spring, & Garfield, 1986; Spring, Lieberman, Swope, & Garfield, 1986; Lieberman, Wurtman, & Chew, 1986), or used a high simple carbohydrate load (Spring, et al., 1983), it could be that the simple carbohydrate in these test meals (sucrose) was responsible for producing the decrement in mood. From these results, one could conclude that while it still decreases tension, a strictly complex carbohydrate meal may cause less of a mood decrement than one high in simple carbohydrates. Further investigation is needed to support this conclusion.

Fluctuations in tension levels could also be caused by anxiety or even pain experienced by the subjects due to repeated intravenous blood draws, rather than a heparin lock as employed by Spring and assosiates (1986). Subjects completed the mood measures before having their blood drawn, so the upward fluctuations in tension measures may also reflect their fear or anticipation of this portion of the procedure. In order to eliminate this possibility, it is necessary to further investigate the differential effects of simple versus complex carbohydrates on mood without the confounding effect of drawing blood.

The fact that the data from the present study does not replicate existing data of increased fatigue and sleepiness levels and decreased alertness following a high carbohydrate load may be due to the fact that the present scores were analyzed across time, whereas most studies looked at an isolated two hour measurement of fatigue levels. In addition, the present study used a between subjects, rather than within subjects design, which may also account for a failure to replicate significant time by meal condition interaction effects on the fatigue and sleepiness scales.

In summary, subjects were less tense, depressed, angry, vigorous, and confused after acclimating to the testing environment and consuming a meal, regardless of whether the meal consisted of simple carbohydrates, complex carbohydrates, or protein. Simple carbohydrates, however, did produce the greatest decrease in tension,as measured by the AD ACL, possibly due to the high elevation of blood glucose levels caused by this meal. The simple carbohydrate meal and protein meal seemed to decrease tension independently of their effects on plasma tryptophan/LNAA ratios. Complex carbohydrates produced less of decrease in tension than the other test meals, yet increased the plasma tryptophan/LNAA ratios. These results conflict with current findings which correlate carbohydrates' calming effect with an increase in tryptophan levels when testing combinations of simple and complex carbohydrate loads. Therefore, further research needs to be done to document the possible differential effect of simple versus complex carbohydrates on mood, and to define the mechanisms through which these effects may be occurring. Incorporation of a larger sample size and a more sensitive within subjects design, could provide such insight and further support the results of the present study.

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Table 1: Test Meal Composition

Meal Condition	Total Calories	Carbohydrate gms/ %	Protein gms/ %	Fat gms/ %
Simple CHO	651	135/83%	13.3/8%	5.8/7%
Complex CHO	631	125/82%	10.1/6%	11.3/12%
Protein	638	9.0/6%	73.1/49%	32.3/45

Table 2: F Scores for Dependent Variables

Dependent Variable	Condition	Time	Time by Condition
SSS Sleepiness	1.80	1.03	0.41
POMS: Tension	1.63	13.39**	0.75
Depression	0.46	5.33*	1.19
Anger	0.36	9.12**	1.36
Vigor	0.08	3.73*	0.87
Fatigue	0.69	1.47	0.74
Confusion	0.09	3.76**	1.44
AD ACL: Energy	0.98	1.21	1.55
Tiredness	2.52	1.17	0.75
Tension	0.88	3.59*	1.85[@]
Calmness	1.03	0.63	0.68
Plasma Glucose	5.43*	4.72*	1.33

*=p<0.01, **=p<0.0001, [@]=p<0.05

Table 3: Significant Mean POMS and AD ACL Tension Scores

Mood Measures	Baseline	30 min	60 min	90 min	120 min	180 min
Tension	47	39	39	39	40	41
Depression	43	39	39	39	39	39
Anxiety	47	40	40	41	41	42
Vigor	48	46	43	44	41	40
Confusion	43	38	40	38	39	39
Tension	1.9	1.5	1.6	1.5	1.5	1.4

Table 4: Mean AD ACL Tension Scores

Condition	Baseline	30 min	60 min	90 min	120 min	180 min
Simple CHO	2.24	1.16	1.68	1.16	1.16	1.20
Complex CHO	1.56	1.84	1.40	1.40	1.42	1.33
Protein	2.00	1.50	1.57	1.40	1.40	1.67
Delayed	1.80	1.60	1.73	1.90	1.93	1.40

Figure 1: Plasma Glucose Levels

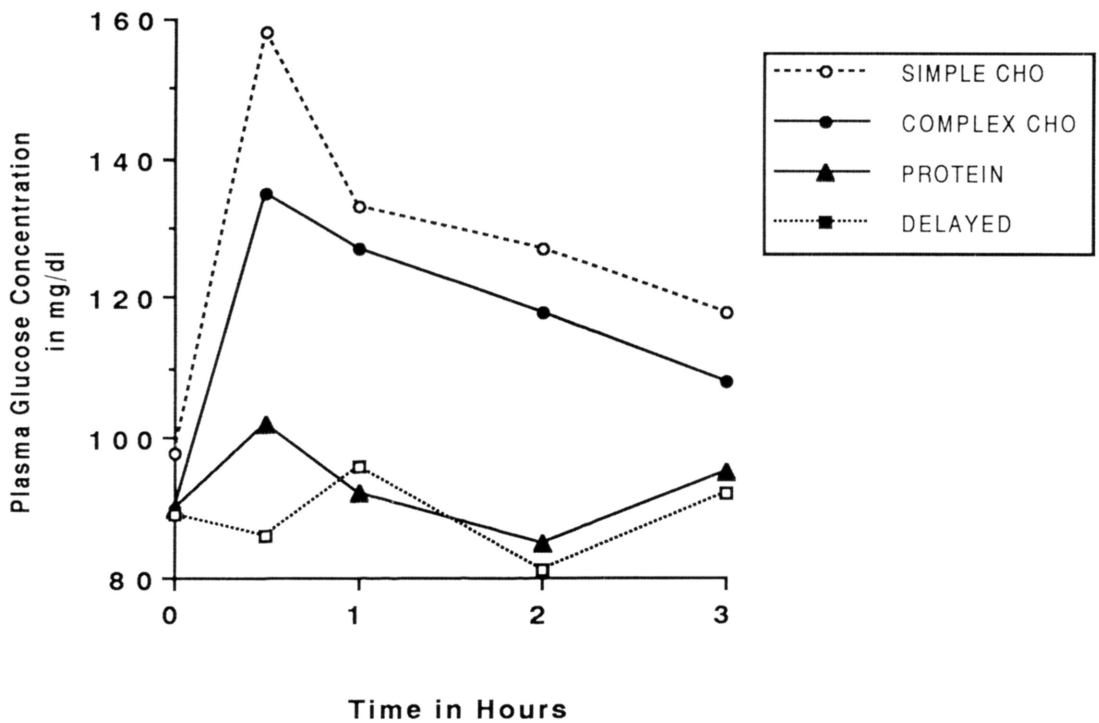

Figure 2: Plasma Tryptophan/LNAA Ratios